VIRTUAL TEACHING APPROACH FOR THE ANALYSIS AND PLANNING OF WIRELESS COMMUNICATIONS SYSTEMS

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Abstract

One of the most important aspects in the field of engineering education is practical training. Very clear examples of this are the laboratories for training in design, development and measurement of electronic systems. However, in other areas of engineering, as for example in the case of communications, where the main objective is the systems analysis and planning, analytical solutions, if is possible, either to the simulation through approaches and algorithms are typically used.

We have developed a set of tools for improving the knowledge and skills in wireless communications systems planning, for students of telecommunications engineering of the “Universidad Politécnica de Madrid”. These tools are of relatively simple use, and they are designed with the intention of a gradual process in learning through the establishment of various educational objective levels. In this paper are presented some of these tools developed and also there is realized an analysis of student assessment in the use of such solutions.

Keywords - Virtual laboratories, b-learning, planning tools, Excel, Java, Matlab

1 INTRODUCTION

Regarding the practical training in instrumental laboratories, when the number of students is very high, when resources to use are very expensive, or when you intend to use some form of e-learning training, a good solution can be using virtual or remote laboratories [1,2]. For the planning of complex systems and in particular for practical training in professional tools, is usual the acquisition of such programmes, normally with a very high cost, or the utilization of demo versions with reduced capabilities. In any case, the use of different functionalities in the tools and professional programs for planning and design communications systems, implies a important effort and high time of dedication, which brings a loss of perspective on the fundamentals on which you want to perform the actions of learning, as well as a lack of freedom in the modification of variables or in the proposal of new solutions.

We have developed a set of tools for improving the knowledge and skills in wireless communications systems planning, for students of telecommunications engineering of the “Universidad Politécnica de Madrid”. These tools are of relatively simple use, and they are designed with the intention of a gradual process in learning through the establishment of various educational objective levels. In the other hand, the use of Learning Management Systems (LMS) or e-learning” platforms like Moodle o WebCT, BlackBoard, as an element of support and follow-up of learning, allows the use of virtual applications that can easily be downloadable or executables on the Internet [3,4]. In the case of universities with face-to-face teaching, the use of this type of solutions is spreading as reinforcement through "blended learning" techniques: classroom and on-line.

In order to increase the skills, knowledge and learning capacities of the students in these subjects, there have been established several levels of applications. The aforementioned levels are closely linked with the teaching aims. The first level is a reinforcement of the theory lectures, especially about the use of formulas (theoretical and empirical) and their application in such topics as propagation, satellite communications, traffic and cell systems.

The second level corresponds to the development of skills and abilities connected with the analysis and planning of these systems of communications. This type of aims enables a higher involvement of the students in the utilization of the available tools, admitting modifications or incorporations for their part, in order to verify the possible influences of the parameters of the used models. The third level of learning would imply capacities of valuation and evaluation of the used or available tools, or even this might mean the design of programs and tools for the system planning of communications.

The developed applications are based on Applets on Java, on spreadsheets of Excel and on programs developed in Matlab and are presented in the following paragraphs. This kind of tools of support to the teaching is being widely developed in many Universities [5,6]

2 WIRELESS COMMUNICATIONS PLANING: CONSIDERED ASPECTS

One of the topics that entail certain complexity of learning on the part of the students is the planning process in systems radio communication and more specifically in the cellular communications systems. The procedures for the design and planning of cellular networks of 2[th] generation like GSM (Global System for Mobile Communications), they are enough good based and they are used independently, or rather of sequential form, the concepts of traffic (capacity) and propagation (coverage), from which it is possible to establish an initial planning of the structure and disposition of clusters, cells and sectors, a distribution of the available channels and an estimation of the Grade of Service (GoS). Nevertheless, in the mobile systems of third generation (3G) based on the technology WCDMA (Wide Code Multiple Division Access), as the system UMTS (Universal Mobile Telecommunications System), the coverage and the capacity they are related and interdependent concepts [7].

The calculations and the planning of the coverage influence the parameters of traffic and capacity and vice versa, all of this makes necessary to establish re-fed processes or to be based on the method of Monte-Carlo to simulate situations and events and to be fitting the different variables up to finding valid solutions. An approximation to this difference and to the processes of planning in both systems can be observed in the figure 1.

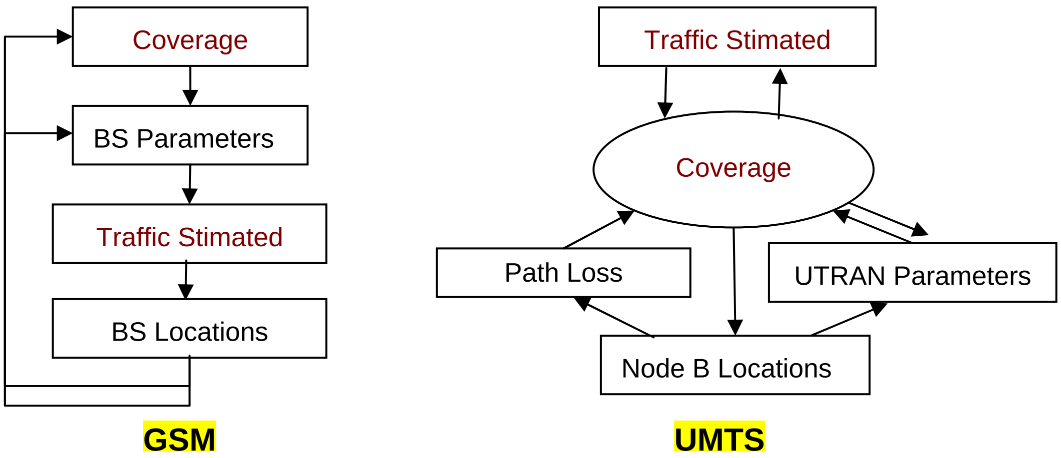


Fig. 1. Scheme of the procedures of planning for networks of mobile communications 2G and 3G.

Additional in the real situations of planning and optimization on the part of the operators of services of mobile communications, and due to the complexity of the same one for these systems of 3 ª generation there are developing technologies of automatic optimization based on different algorithms, which from the quality indicators (KPI) are capable of being living together the parameters of the Nodes B to obtain more efficient results [7].

This means an extensive knowledge of the influence of the parameters of the used models, both of propagation and of traffic. Therefore the use of specific and independent applications for the knowledge of this influence can be very interesting for the Final Degree Project or for activities of development and research.

3 DESCRIPTION OF THE DEVELOPED APPLICATIONS

In order to make easy the learning of the foundations and procedures of planning in the different levels of aims enunciated previously, it has been developed several applications.

For the first level, where there is claimed a checking of the theoretical enunciated knowledge and that makes the students possible to identify and to compare the models of propagation and traffic and the results of the planning, several Applets of Java have been developed. In these Applets, using the selection of models and the introduction of the suitable parameters of the same ones there are obtained different numerical and graphical results. This type of solutions avoids the use of commercial programs demos, which they imply a high time of learning of their functionalities, with the loss, since already it has been commented previously, of the theoretical foundations into which it is interested to look deeply.

The figure 2 shows the Applet of Java developed for the study and comparison of the models of propagation and calculation of the links between the base station and the mobile stations. In this application it is possible to visualize jointly and modify the main parameters of the systems of transmission and reception, the equations and the variables of the propagation models used, as well as the results of the link budgets, both in numerical and graphical form, in the last case depending on the distance.

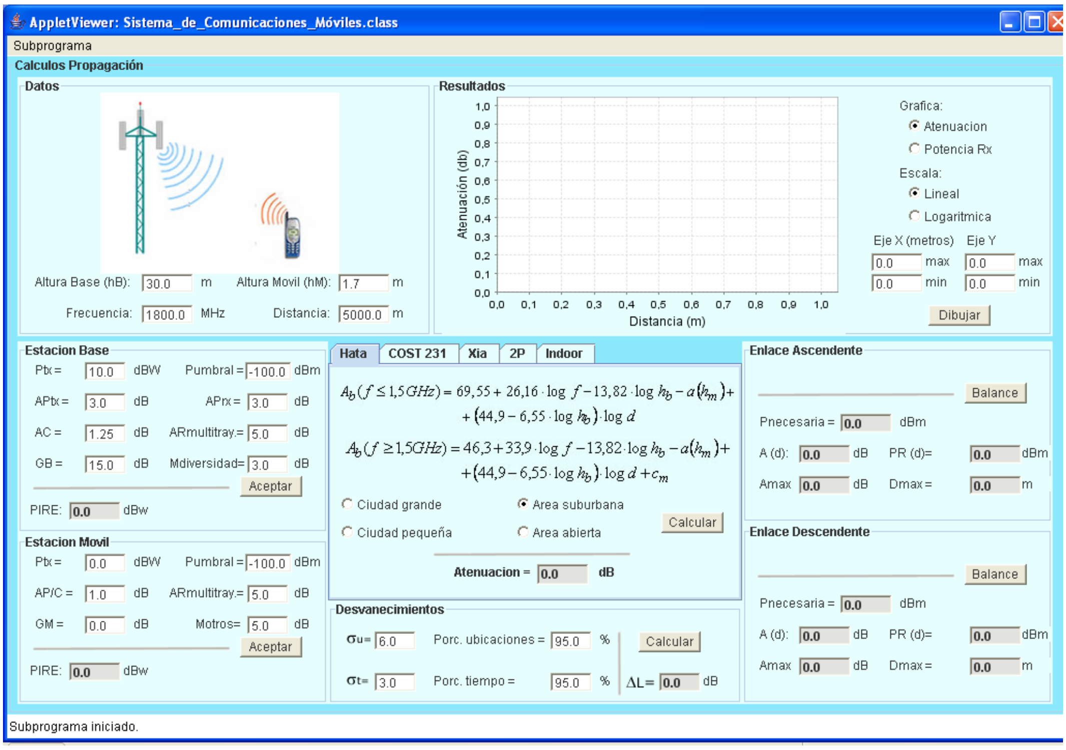


Fig. 2. Applet of Java for the study of propagation models of the mobile communications systems

In the figure 3 is represented a graph of comparative results with two models of propagation.

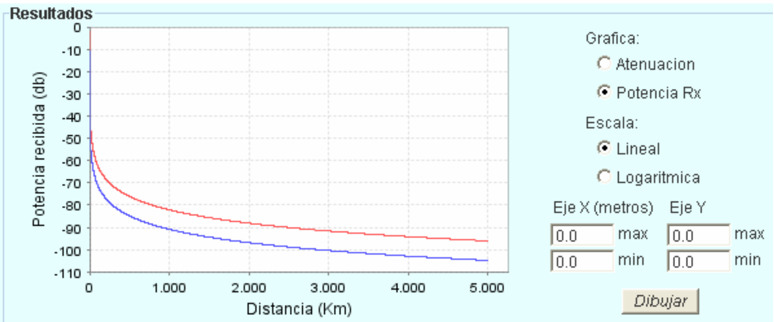


Fig. 3. Results of the power/energy received depending on the distance for two different models..

In the same way, it has been developed an Applet of Java for the calculation and the graphical visualization of the grade of service for the distributions of several traffic models. The most used in the planning of mobile systems, both the cellular systems and in private systems are Erlang B and C.

For the second level of aims, those that allow calculations and elaborated analyses, and certain capacity of development, design and evaluation of the planning have realized different applications on spreadsheets in Excel. Many applications of real planning on the part of the companies and operators are based on spreadsheets, because they allow a great flexibility in order to be modified and updated. Besides, this kind of solutions of calculation allow to include a programming of functions and subroutines in Visual Basic, Visual Basic focused on Applications (VBA), in a simple way and that increases to a great extent their possibilities in those cases in which a recurrent process is necessary. In the figure 4, it is shown a part of the spreadsheet used for the analysis of the propagation and the links balance.

3	ESTACIÓN BASE (BS)					ESTACIÓN MÓVIL (MS)			
4	Parámetro	Abrev	Valor	Unidades		Parámetro	Abrev	Valor	Unidades
5	Altura	h_b	30	m		Altura	h_m	1,7	m
6	Frecuencia	f	1000	MHz		Frecuencia	f	1000	MHz
7	Potencia transmitida	P_{Tx}	10	dBW		Potencia transmitida	P_{Tx}	0	dBW
8	Atenuación pasivos	α_p	3	dB		Atenuación pasivos/cable	$A_{p/c}$	1	dB
9	Atenuación cable	α_c	5	dB/100m		Ganancia	G_{MS}	0	dB
10	Longitud cable	l	25	m		PIRE	PIRE	-1	dBW
11	Atenuación total cable	$\alpha_c \cdot l$	1,25	dB		Sensibilidad (Pot. umbral)	S	-100	dBm
12	Ganancia	G_{BS}	15	dB					
13	PIRE	PIRE	20,75	dBW					
14	Sensibilidad (Pot. umbral)	S	-100	dBm					
15									
16	DESVANECIMIENTOS								
17	Correciones y mejoras	Abrev	Valor	Unidades		Correciones y mejoras	Abrev	Valor	Unidades
18	por multitrayecto y ruido	ΔR_{BS}	5	dB		por multitrayecto y ruido	ΔR_{MS}	5	dB
19	por diversidad en la BS	Gd	3	dB		Otros márgenes (cuerpo...)	Mo	5	dB
20	Parámetro			Símbolo	Valor	Porcentaje			%
21	Desviación por ubicaciones			σ_u	6	de ubicaciones			95
22	Desviación por tiempo			σ_t	3	de tiempo			95
23	Margen por desvanecimiento lento			ΔL	11,03 dB				
24	Potencia necesaria BS	P_{nbs}	-86,97	dBm		Potencia necesaria MS	P_{nms}	-78,97	dBm
25									
26	MODELOS DE PROPAGACIÓN								
27	Parámetro	Abrev	Valor	Unidades		Enlace descendente (DL)	Frecuencia:	1000	MHz
28	Distancia	d	1000	m					
29	Okumura Hata								
30	○ Ciudad pequeña o mediana		○ Área suburbana						
31	◉ Ciudad grande		○ Área abierta			Atenuación	A_b	127,17	dB
32	COST 231								
33	Área urbana densa								
34	Altura del tejado	h_r	18	m		Atenuación espacio libre	A_{el}	92,45	dB
35	Ancho de la calle	w	15	m		Difracción tejado-calle	A_{rts}	25,583	dB

Fig. 4. Spreadsheet for the analysis and planning of the links of mobile communications.

Figure 5 shows graphical results of the spreadsheets for the part corresponding to the study, analysis and planning of traffic. In this case different models have been developed: Erlang B, C and Engset

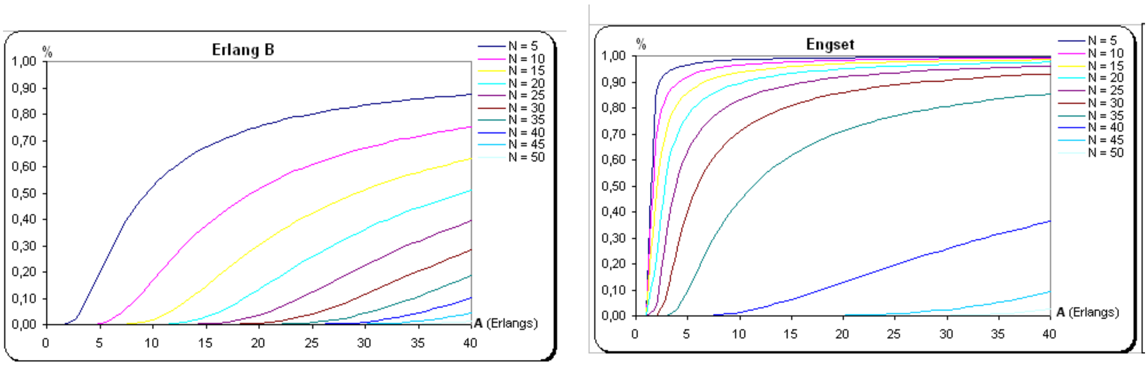


Fig. 5. Graphical results for the Grade of Service depending on the offered traffic and the number of channels according to the Engset distribution.

Provided that the format of the equations in Excel does not allow an easy interpretation of the equations and with the purpose that the students do not lose sight of dress the equations of the models, the mathematical expressions of the same ones are included in the proper spreadsheet. In the figure 6 can be observed some of these equations for the models of propagation and for a distribution of probability.

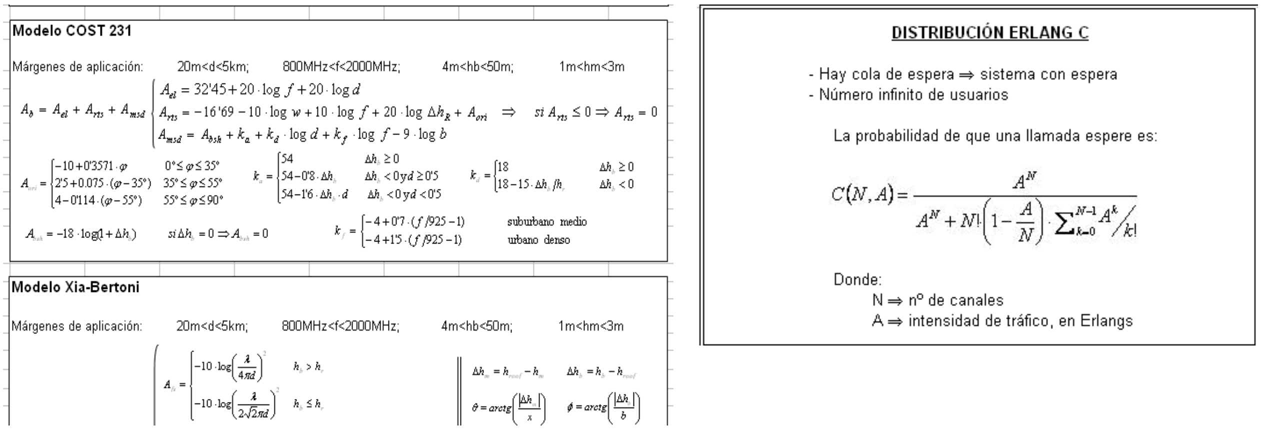
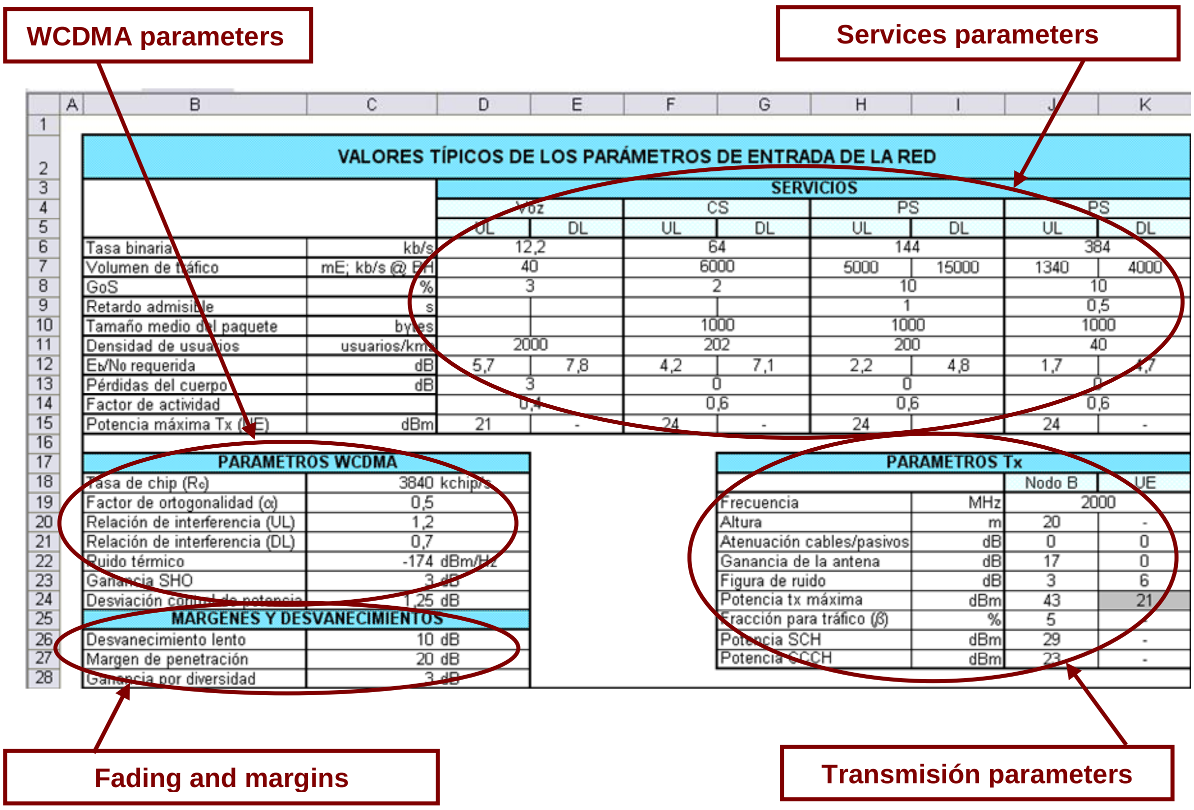


Fig. 6. Representation of the equations in the spreadsheets

For the process of planning in UMTS, which is the most complex procedure, also it has been developed an application in Excel and an Applet of Java that gathers the previous developments. Figure 7 represents the sheet of Excel with the input data, used for the planning of different services in mobile communications 3G



VALORES TÍPICOS DE LOS PARÁMETROS DE ENTRADA DE LA RED									
		SERVICIOS							
		Voz		CS		PS		PS	
		UL	DL	UL	DL	UL	DL	UL	DL
Tasa binaria	kb/s	12,2		64		144		384	
Volumen de tráfico	mE; kb/s @ BH	40		6000		5000	15000	1340	4000
GoS	%	3		2		10		10	
Retardo admisible	s					1		0,5	
Tamaño medio del paquete	bytes			1000		1000		1000	
Densidad de usuarios	usuarios/km2	2000		202		200		40	
Eb/No requerida	dB	5,7	7,8	4,2	7,1	2,2	4,8	1,7	4,7
Pérdidas del cuerpo	dB	3		0		0		0	
Factor de actividad		0,4		0,6		0,6		0,6	
Potencia máxima Tx (UE)	dBm	21	-	24	-	24		24	-

PARAMETROS WCDMA	
Tasa de chip (Rc)	3840 kchip/s
Factor de ortogonalidad (α)	0,5
Relación de interferencia (UL)	1,2
Relación de interferencia (DL)	0,7
Ruido térmico	-174 dBm/Hz
Ganancia SHO	3 dB
Desviación control de potencia	1,25 dB
MARGENES Y DESVANECIMIENTOS	
Desvanecimiento lento	10 dB
Margen de penetración	20 dB
Ganancia por diversidad	3 dB

PARAMETROS Tx			
		Nodo B	UE
Frecuencia	MHz	2000	
Altura	m	20	-
Atenuación cables/pasivos	dB	0	0
Ganancia de la antena	dB	17	0
Figura de ruido	dB	3	6
Potencia tx máxima	dBm	43	21
Fracción para tráfico (β)	%	5	-
Potencia SCH	dBm	29	-
Potencia CCCH	dBm	23	-

Fig. 7. Spreadsheet for the study and system planning UMTS.

Figure 8 sows some of the windows of introduction of data and numerical results of the Applet developed as educational tool used for the analysis and the system planning of mobile communications UMTS.

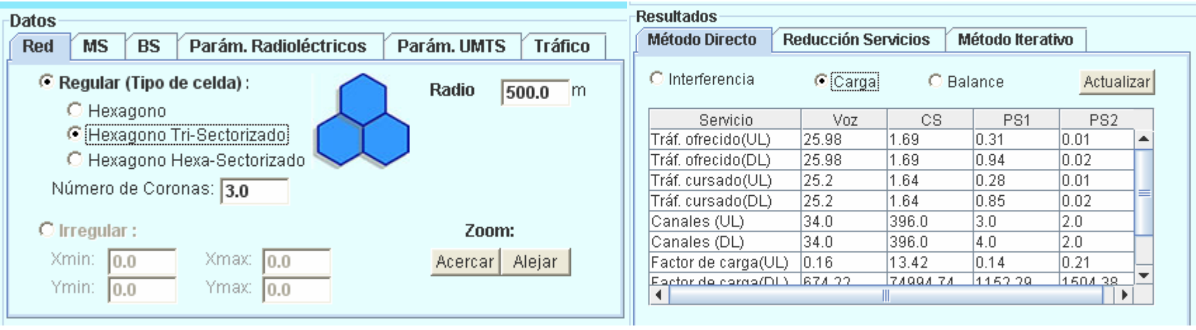


Fig. 8. Windows of information and results of the educational tool by means of an Applet Java for systems of communications

Some graphical results of the application, corresponding to the theoretical coverage, to the simulated distribution of users and to the interference phenomena are showed in the figure 9.

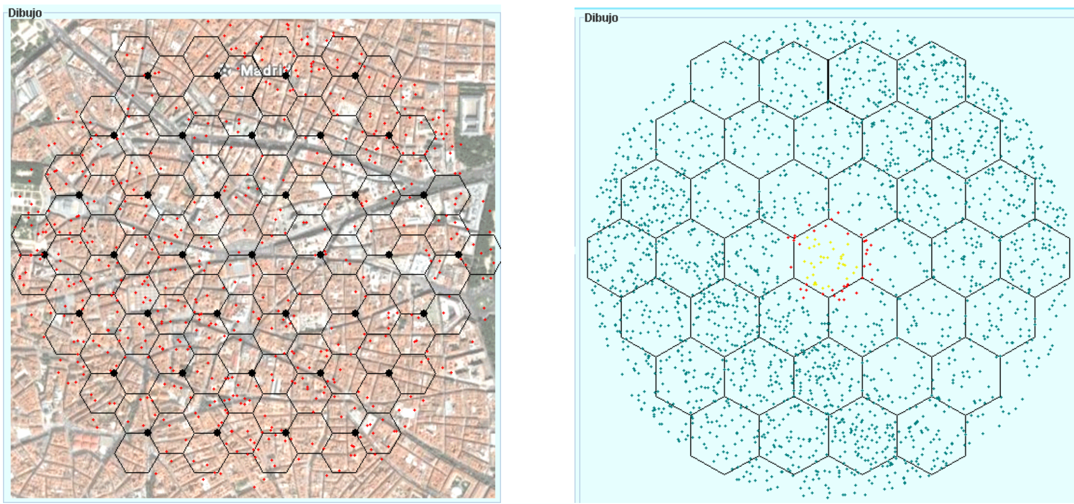


Fig. 9. Windows of graphical results of the application.

For the third level of aims, corresponding to research activities, development of tools and the validation of the same ones, specific programs has been elaborated in some language of high-level programming as C, or in Matlab, which simplifies to a great extent the handling of processing of data and graphs.

4 ANALYSIS OF THE VALUATION OF THE TOOLS FOR THE STUDENTS

The use of the series of tools of calculation, planning and design for wireless communications and mobile systems of communications presented in this lecture and lodged at a platform of virtual education, has been very widely accepted by the students.

After the first reticence to the use of this kind of tools as a procedure of learning of certain competitions and skills, for thinking that they were increasing the load of work and were not impacting on the knowledge for a possible final evaluation, they have been very well valued when they have been included in the resolution of problems and cases by an evaluation that has an influence on the final mark.

In order to value the use of these virtual solutions and to achieve a feedback on this use, it has been realized during the last years many on-line polls among the students who have used them, being 60 surveys in all. In these surveys different questions have been realized on them: teaching and methodological issues, the awaken interest, the procedures of evaluation of the subject on the one hand and on other one on the using of the platform and of the virtual tools previously showed.

In general the results are satisfactory enough, but it is necessary to emphasize the very good valuation of the use of a b-learning methodology, based on the platform Moodle and on the use of the simulation programs. Some of the realized questions and the average values obtained for a scale between 1 (very negative) and 5 (very positive) are reflected in the table 1.

Table 1. Questions and results of the on-line polls carried out among the students

Categories and questions	**Average grade (about 5)**
Teaching, methodological and evaluation issues	
1. About the program and the organization suitability to the aims	4,2
2. About the suitability of the contents and the format of the topics	3,9
3. About the suitability of the invested time	3,6
4. About the level of knowledge that student think that he/she has acquired during the subject	4,1
5. About the level of the professional competences	3,8
6. Procedures of evaluation	3,6
……	
Technical issues of the platform Moodle and of the virtual teaching	
11. The platform Moodle is friendly and easy to use	4,6
12. The student has not had technical problems of access or utilization	4,1
13. Easiness of follow-up of the subject using Internet as support to the teaching	4,4
14. The utilization of virtual tools makes easier the learning process to the student	4,2
……	

In these results it is possible to notice in general the good mark obtained for the different considered aspects. It is of emphasizing the very good mark obtained in the technical aspects like the facility of use of the platform Moodle and the help to the follow-up of the subject by means of the availability of educational material in Internet, included the virtual tools.

All of this makes a great improvement about the consideration of the methodological aspects, especially in those which are connected with the organization, the contents and the format of the topics. Both aspects with lower marks are connected with the invested time and the procedures of evaluation that as it tends to happen, always is higher on the part of the students.

In the survey also the students were asked about the most positive aspects and more negatives ones of the subject. Among the most positive aspects getting closer to the professional reality of the wireless communications and to be able to complete part of the activities of the subject using Internet, has been indicated. As for the most negative aspects it appears the invested time and the need of a constant follow-up of the subject.

5 CONCLUSIONS

The applications developed in Java and Excel simplify to a great extent the learning process, first of the proper tool, provided that one of the specifications of design was the ease of use on the part of the students, and secondly these applications makes easy working with the mathematical and empirical models used in the subjects of Radio communication and Mobile Communications.

The work of development for the accomplishment of this kind of solutions is very important, but it has been carried out by the own students by means of final projects, and as a result, this development also improves the training of some students.

The utilization of the tools and applications previously mentioned they have allowed the achieve of different teaching aims connected with make easy the comprehension, the analysis, design and system planning of wireless communications.

Moreover during these years procedures of continuous assessment have been joining in the EUIT of Telecommunication of the UPM. For this kind of system of evaluation there is very suitable the use of programs and simulations as the presented ones, in other words we are talking about a virtual approach in to the education, which allows a more continued work of the student and based on the acquisition of responsibilities.

The surveys realized on the valuation of the use of a virtual approach to the education, shows a very positive valuation on the part of the students. In order to improve and to extend their use is necessary to check the invested time required, as well as the related aspects of evaluation

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